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This work examines the thermal boundary resistance between high-Tc superconducting films and insulating substrates. In particular we compare c-axis and a-axis films and different oxygen stoichiometries. Comparison of c-axis films shows very little temperature dependence; a-axis films show strong temperature dependence from 100 K to room temperature. This temperature dependence disappears upon reducing the oxygen content of the films.

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FINAL REPORT

to the

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

for a program in

BOUNDARY EFFECTS IN HIGH-T_c SUPERCONDUCTING DEVICES

for the period 7/1/93-6/30/96

under AASERT Grant F49620-93-1-0362

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Final Technical Report
for the period 7/1/93-6/30/96

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I. Introduction

Our AASERT program centers around the investigation of boundary effects with high-Tc superconductors. The motivations for the project have been twofold. The first is to understand charge and heat transport through boundaries between metals or insulators and high Tc materials. Such understanding is important for the understanding of the elementary excitations in the high-Tc materials, can help understand the symmetry of the order parameter, and can point to materials problems in trying to create an ideal interface with high-Tc superconductors.

The second motivation to study boundary effects relates to the possible applications of high-Tc superconductors. As we recently concentrated on the study of thermal boundary effects, this subject is of chief importance for the fabrication of bolometers made of high-Tc films. In the past, thermal boundary resistance measurements between high-Tc and various oxide substrates on which they were grown showed anomalously large values in the interesting range of temperatures around Tc~90 K. Simple analysis based on acoustic mismatch theory (i.e. mismatch of the acoustic impedance of the high-Tc and the substrate) predicted boundary resistances 100 times smaller than the one found experimentally. In our AASERT proposal we proposed to study this discrepancy and in fact conjectured that it is related to the fact that heat is carried out in the high-Tc by elementary excitations that do not exist in the substrate, such as spin fluctuations.

II. Status of Effort

In the previous year we tried to perform more detailed experiments to better understand the source of the above discrepancy. For the first time we compared thermal boundary resistance measurements on c-axis and a-axis films of YBaCuO on $LaAlO_3$ and $SrTiO_3$ Our preliminary measurements on which we reported last year showed difference in size between the boundary resistance of these two films, with lower values for the a-axis films. In the past year we continued these measurements, investigating the temperature dependence of the boundary resistance of these two types of films. We also succeeded in measuring the boundary resistance through and below the superconducting transition, finding an anomaly at the transition. However, maybe most importantly, we have found a strong nonlinear behavior in the thermal boundary resistance, an effect that was not observed previously. Our findings may point to the fact that previous results of thermal boundary resistance were over-estimating the resistance due to the strong nonlinear effects. The source of the nonlinearities however is not clear. Close examination of the epitaxy of the films on the substrates reveal that it is not perfect. In fact at ~90 K, the relevant temperature, the phonon mean scattering length is of the order of the morphological imperfections of the boundary. Thus, a possible explanation for the strong nonlinearities is the morphology of the interface.

The second part of this AASERT program, and one which is more directly related to the Stanford Air Force program on high-Tc materials and devices, is the fabrication of nanojunctions of N/S and N/I/S type. To this end we constructed a new, innovative STM system that uses the STM tip to field-evaporate mounds of metal on the high Tc surface. More specifically, we concentrated on the deposition of small Au mounds, ~400 Å in diameter and ~100 Å high, on BiSrCaCuO single crystals. The process that we developed which utilizes UHV is now routinely used to fabricate Au/BiSrCaCuO junctions.

III. Accomplishments

As noted above, we can report on two main accomplishments in this project. The first is the finding of the strong nonlinear effects in the thermal boundary resistance as a function of the applied power. Such an effect is very important in constructing bolometers made of high-Tc films on an oxide substrate. Since in bolometric detection only low power is involved, it could be that previous measurements that pointed to large boundary resistance and hence inability to use these devices, were not relevant.

In the electrical boundary resistance problem we achieved an important milestone in being able to routinely produce nano-contacts between Au and high-Tc BiSrCaCuO crystals.